

# Preliminary Study on the Potential of East Coast of Peninsular Malaysia's Silica for Foundry: Case Study - Terengganu

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**(Abstract)** In foundry, most of the molds and cores are based on silica sand since it is the most readily available material at lowest cost. In this study, several silica sand samples from six locations in Terengganu's state have been investigated for the potential of Terengganu's silica for foundry use. The important properties studied are grain fineness number, size distribution, total clay content, specific surface area, grain classification and chemical composition. The results shows that all Terengganu's silica sand have high percentage of silica content within the range of 97.2 - 98.7%, where Telaga Papan sand has the highest silica content of 98.7%. On the contrary, all the samples show small percentage of iron oxide between the ranges of 0.06% to 0.25% with Kuala Abang has the highest of 0.25% of iron oxide. As foundry materials, the silica content should be more than 95%. Based on these results, regardless of grain fineness number (GFN), the sand was found to be suitable candidate to be used as foundry materials. However, if the average grain size represents by GFN is taken into consideration, Kuala Abang's silica with 57 GFN and Jambu Bongkok's silica with 49 GFN are most suitable as foundry materials.

**Keywords:** silica sand; Grain Fineness Number; Average Grain size; silica content

## 1. INTRODUCTION

Quality casting production relies on the selection of quality raw material as well as the quality processes throughout the foundry operation. Sand is a main and common material used in the sand mold of foundry and its characteristics give a great deal of influence to the mold properties. Foundry sands are composed almost entirely of silica ( $\text{SiO}_2$ ) in the form of quartz [1]. The composition, purity, size and the shape of the sand are important factors to achieve good molding process. Sand for molding is usually classified into three groups that are natural sand, silica sand and special sand. The examples of silica sand are sea sand, shore sand, river sand and lake sand. Both natural and silica sand are composed of silica ( $\text{SiO}_2$ ). Olivine, zircon and chromite sand are classified as special sand which is expensive and only available in some places in the world. A few literatures on this topic have been published in recent years [2-4]. Sand with high silica content gives higher refractoriness than that of low silica content. Both alumina and magnesium oxide have higher refractoriness than silica. The size distribution of the sand affects the quality of the castings. Coarse grained sand allows metal penetration into the molds and cores giving poor surface finish to the castings. Fine grained sands yield better surface finish but need higher binder content [5]. Most foundry sands should fall within 50-60

Grain fineness number (GFN) or 220-250 microns average grain, 95-96% silica content, 0.3% maximum iron oxide content, 0.5% max clay content, 120-140 $\text{cm}^2/\text{g}$  specific surface area and 2% maximum fines content which is referring to the particle size below 200 mesh. Grain shape is defined in terms of angularity and sphericity. Sand grains vary from well-rounded to rounded, sub rounded, sub angular, angular and very angular. Within each angularity band, grain has high, medium and low sphericity. The best foundry sands have grains which are rounded with medium to high sphericity giving good flowability with high strength at low binder additions. The main objective of this study is to investigate the potential of Terengganu's silica as a molding material for casting process.

## 2. METHODS

The particle size of the sand collected was measured using Ro-tap sieve shaker consists of shaker and 14 sieves which available at Foundry Technology Program, SIRIM Berhad. The samples were labeled as KA1, KA2, KA3 for samples taken at Kuala Abang; TP1, TP2, TP3 for samples taken from Telaga Papan; JB1, JB2, JB3 for samples taken at Jambu Bongkok; Merang1, Merang2, Merang3 referring to the sand of Merang, RHU10 (1), RHU10 (2), RHU10 (3) refer to the sample taken at Rhu Sepuloh and PK1, PK2, PK3 refer to the

sample of Pulau Kerengga. **Figure 1** shows the location of the samples taken in this study.

The samples were then placed onto the topmost sieve and the sieve was set on the ro-tap shaker. Then the shaker was operated for 15 minutes and the weight of sand in every sieve was weighed using electronic balance. Percent retained on the individual sieve was calculated by dividing weight retained on the individual sieve by the total weight of the sample used. From these data, the grain distribution for each samples were obtained and the Grain Fineness Number (GFN) was determined using the following equation:

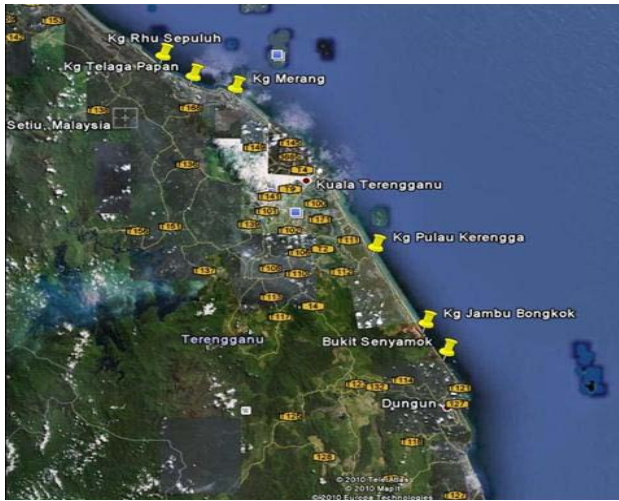
$$GFN = \frac{\sum(W_n \times S_n)}{\sum W_n} \quad (1)$$

Where,

$GFN$  = Grain Fineness Number,

$W_n$  = Weight of sand

$S_n$  = Grain fineness coefficient



**Figure 1:** Location of silica sand sample taken for this study.

Fine content which is shown by percentage of grains with the size below 200 mesh was also calculated from these results. X-Ray Fluorescence Spectrometer (XRF) was used to study the chemical composition of these samples. Grain classification was done using Scanning Electron Microscope (SEM) at 100X and 20X magnification. This characterization gave the picture of grain shape that affects the strength of the moldings. To determine the total clay content in silica sand, rotating sand washer was used. 50 gram of dried sample was placed into the glass bottle followed by 475 ml of distilled water and 25 ml sodium hydroxide (NaOH). Bottle was set on rotating sand washer and the washer was allowed to operate for an hour. Sand sample was washed until clear solution was obtained. The sand had been dried in the oven and the remaining sand was weighed. The percentage of total clay content was given by the different in weight [6].

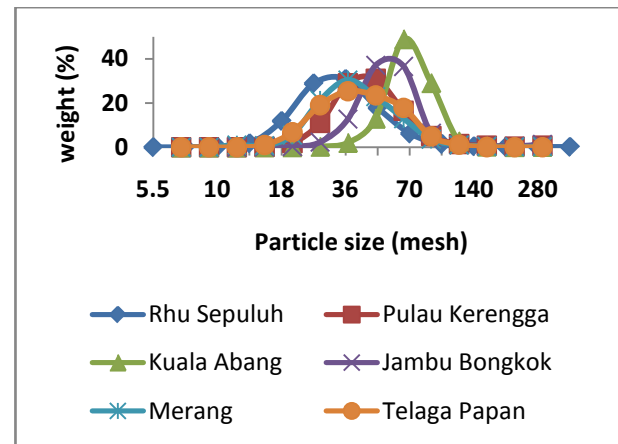
$$\text{Total clay content} = \frac{\text{sample weight} - \text{remaining weight}}{\text{sample weight}} \quad (2)$$

The measurement of sand specific surface area was performed using sand surface testing apparatus. 50 gram of sand sample was filled into the tunnel tube and time taken for

kerosene to travel through the sample in the tube was measured. Actual specific surface area is derived from the measured sinking time and the sand volume using a graph accompanying the instrument [7].

### 3. RESULTS AND DISCUSSIONS

Fine-grain sand produced better surface finish but needed higher percentage of binder. Sand with 220-250 microns average grain size or 50–60 Grain Fineness Number (GFN) is suitable to produce casting with good surface finish. From the grain distribution plot shown in **Figure 2**, it can clearly be seen that Kuala Abang's silica has the smallest average grain size followed by Jambu Bongkok's silica. The coarsest sand is at Rhu Sepuluh followed by Telaga Papan and Merang. By comparing the grain distribution as shown in **Figure 2** and the location of sampling in **Figure 1**, it can be deduced that the sand in the northern region is coarser than the sand at the southern region of Terengganu. By using Eq.1, GFN was calculated and established that Kuala Abang has 57 GFN, Rhu Sepuluh 29 GFN, Telaga papan 35 GFN, Pulau Kerengga 41 GFN, Jambu Bongkok 49 GFN and Merang 35 GFN. The GFN indicates that finer sand has wider surface area than coarser sand leading to higher specific surface area that is 100cm<sup>2</sup>/g for Kuala Abang and 68cm<sup>2</sup>/g for Jambu Bongkok.



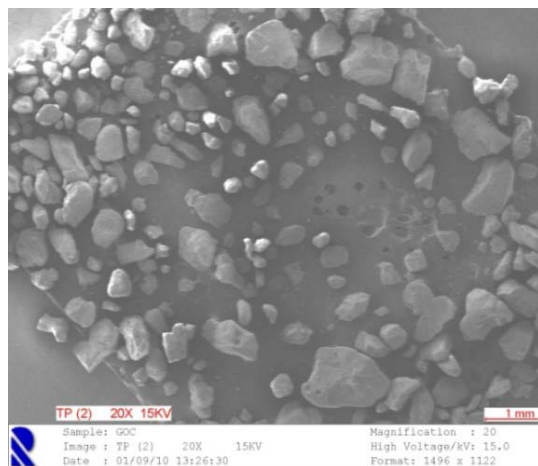
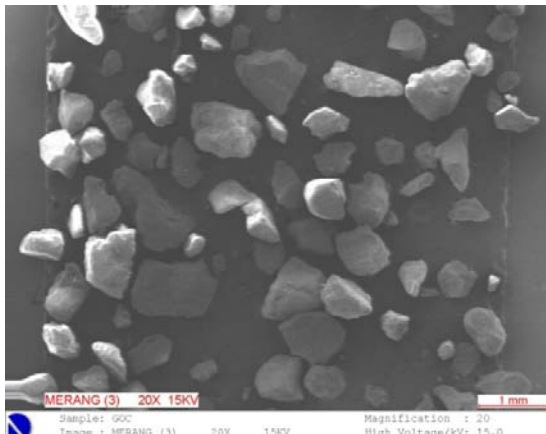
**Figure 2:** Grain distribution of Terengganu's silica sand.

In order to use low amount of binder level to be used, fine content that is grains with particles size below 200 mesh should be less than 2%. From the grain distribution evaluation, it was also found that all the samples contain small percentage of fine silt ranging from 0.1% to 1.7%, once again confirms that all the silica sand taken from six locations is suitable to be used as molding material. Total clay content as shown in **Table 1** shows the same trend as fine silt that is roughly constant between 0.34 % and 1.11%.

**Table 1:** Clay content, fine content and specific surface area of Terengganu's silica

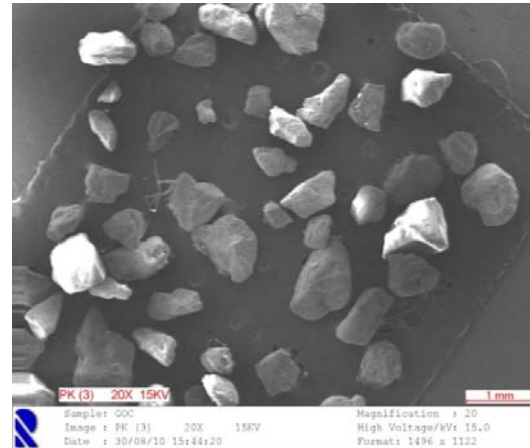
Location	Specific surface area (cm <sup>2</sup> /g)	total clay (%)	Fine content (%)
Jambu bongkok	68	0.94	1.68
Merang	52	1.06	0.52
Kuala Abang	100	0.52	0.39
Rhu Sepuluh	25	0.72	0.30
Telaga papan	42	0.34	0.11
Pulau kerengga	42	1.11	1.02

The shape of sand also influences the packing density and sand surface area and the consumption of binder is proportionate to the sand surface area. The best foundry sand is generally rounded with medium to high sphericity grains. As shown in the **figure 3**, Merang sand has angular grains, low sphericity mixed with angular grains, medium sphericity. The same result also obtained for Telaga papan as shown in **figure 4**, that is mostly, consists of angular with medium sphericity grains and angular with low sphericity grains. However, Pulau Kerengga and Rhu Sepuluh sands, shown in **figure 5** and **figure 6** only show the presents of angular with low sphericity grains. Slightly different from the other, Kuala Abang and Jambu Bongkok sand have portions of sub rounded with medium sphericity grains.

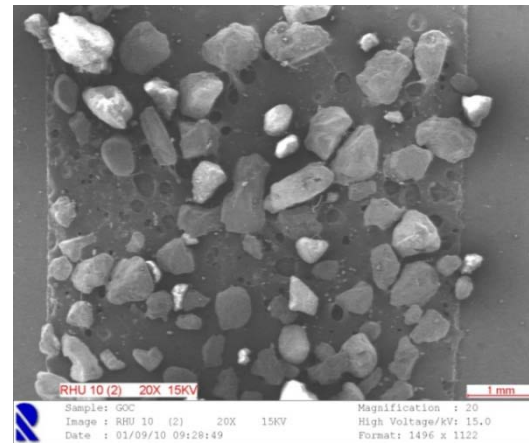


**Figure 3:** Grain shape of Merang's silica sand magnified at 20X

**Figure 4:** Grain shape of Telaga Papan's silica sand magnified at 20X.



**Figure 5:** Grain shape of Pulau Kerengga's silica sand magnified at 20X.



**Figure 6:** Grain shape of Rhu Sepuluh's silica sand magnified at 20X.

Chemical composition of the silica sand was studied using Shimadzu XRF-1700, X-Ray Fluorescence Spectrometer and the loss on ignition (LOI) was performed using CMTS furnace at 1000°C. The results are shown in **table 2**.

**Table 2:** Chemical composition of silica sand.

Oxide	Weight percentage (%)					
	Telaga papan	Rhu Sepuluh	Kuala Abang	Pulau Kerengga	Jambu Bongkok	Merang
SiO <sub>2</sub>	98.67	98.34	97.86	98.38	97.19	98.31
Al <sub>2</sub> O <sub>3</sub>	0.55	0.66	0.83	0.56	1.23	0.57
Fe <sub>2</sub> O <sub>3</sub>	0.09	0.12	0.25	0.10	0.20	0.09
TiO <sub>2</sub>	0.04	0.05	0.36	0.06	0.20	0.03
CaO	0.07	0.05	0.08	0.06	0.06	0.09
MgO	0.05	0.06	0.07	0.06	0.06	0.06
MnO	0.01	0.01	0.02	0.01	0.01	0.00
K <sub>2</sub> O	0.10	0.17	0.14	0.11	0.26	0.10
Na <sub>2</sub> O	0.05	0.05	0.06	0.06	0.06	0.05
P <sub>2</sub> O <sub>5</sub>	0.04	0.05	0.06	0.06	0.05	0.05
SO <sub>3</sub>	0.05	0.05	0.05	0.06	0.05	0.08
LOI	0.30	0.43	0.30	0.53	0.67	0.60

The result shows that the entire sand are rich with silica content with the highest percentage found in Telaga Papan's sand. This sand satisfied the requirements for refractoriness in terms of their silica content. The presents of  $\text{Fe}_2\text{O}_3$ ,  $\text{K}_2\text{O}$  and  $\text{Na}_2\text{O}$  would reduce the refractoriness thus lowering the fusion temperature. However, as clearly be seen in the table, the percentage of iron oxide in all silica samples are lower than 0.3% which also showed that all the sand meets the criteria as a molding sand. Similarly as iron oxide, Terengganu silica contain only small percentage of  $\text{K}_2\text{O}$  and  $\text{Na}_2\text{O}$  and this percentage will not affect the refractoriness of the sand.

#### 4. CONCLUSION

By considering the silica percentage, percentage of iron oxide,  $\text{K}_2\text{O}$ ,  $\text{Na}_2\text{O}$ , fine silt and total clay content, all of the silica sand of Terengganu region show high potential to be used as molding material, provided it must be grinded prior to molding. On the other hand, the silica sand of Kuala Abang and Jambu Bongkok can be used without further processing due to the size distribution satisfies the casting process requirement.

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